Influence of stocking rate and steroidal implants on growth rate of steers grazing toxic tall fescue and subsequent physiological responses[1]

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ABSTRACT: An 84-d grazing experiment was conducted in 2 growing seasons to evaluate interactions of stocking rate and steroidal implants with BW gain and symptoms of toxicosis in yearling steers grazing endemic endophyte-infected (E+) tall fescue (*Festuca arundinacea* Schreb.). A 4×2 factorial design was used to evaluate 4 stocking rates (3.0, 4.0, 5.0, and 6.0 steers/ha) with or without steroidal implants (200 mg of progesterone + 20 mg of estradiol benzoate). Treatment combinations were randomly assigned to eight 1-ha pastures of E+ Kentucky-31 tall fescue (i.e., treatments were not replicated). Treatment effects were analyzed for ADG, total BW gain per hectare, forage availability, and hair coat ratings. At the conclusion of grazing in the second year (22 June), steers were placed on a bermudagrass [*Cynodon dactylon* (L.) Pers.] pasture, and rectal temperatures and serum prolactin concentrations were monitored for 10 d to assess carryover effects of stocking rate and steroidal implants on recovery from toxicosis-related heat stress. Forage availability differed ($P < 0.001$) between years, but there were no year $\times$ treatment interactions ($P > 0.10$). There was an implant $\times$ stocking rate interaction ($P < 0.05$) on ADG. Differences between the slopes in the regression equations indicated that ADG responded to implantation when stocking rates were low, but the response diminished as stocking rate increased. Stocking rate did not influence ($P = 0.89$) postgraze rectal temperature, but the regression intercept for implanted steers was 0.4°C greater ($P < 0.05$) than for nonimplanted steers, and the difference was consistent across the entire 10-d fescue-free grazing period. Concentrations of prolactin increased during the 10-d fescue-free grazing period, but trends differed due to an implantation $\times$ stocking rate interaction ($P < 0.05$). Results indicate that implantation with progesterone + estradiol benzoate increases ADG with lower stocking rates, but the effect diminishes with increased grazing intensity. Implantation with steroid hormones increased rectal temperatures, but during a fescue-free grazing period rectal temperatures and serum prolactins for implanted and nonimplanted steers returned to values indicative of a stable and healthy status in a 192- to 240-h (i.e., an 8- to 10-d) period. However, because the treatments used in this study were not replicated, these observations need to be confirmed with replicated studies.

Key words: beef cattle, *Festuca arundinacea*, forage, *Neotyphodium coenophialum*, tall fescue, toxicosis

INTRODUCTION

Tall fescue covers approximately 35 million ha in the United States and is the predominant cool-season perennial grass (Thompson et al., 2001). An endophytic fungus (*Neotyphodium coenophialum*) infects tall fescue plants, inhabits greater than 90% of the tall fescue pastures (Sleper and West, 1996), and produces toxins that induce toxicosis (Sleper and West, 1996). This malady has symptoms that include retention of rough hair coat, elevated body temperature, labored respiration, and decreased serum prolactin and BW gain (Schmidt and Osborn, 1993).

Heat stress and poor BW gain from toxicosis are most severe at the onset of high ambient temperature and humidity during the spring and summer (Hemken et al., 1981). Body weight gains of steers have been improved during this period by feeding concentrates (Aiken et al., 1998) or by moving cattle to a warm-season grass pasture in the late spring (Aiken and Piper, 1999). Use of steroidal implants is another approach to im-

prove calf performance on endophyte-infected (**E+**) tall fescue (Bransby et al., 1994). Coffey et al. (2001) reported that inplanting with trenbolone acetate and estradiol resulted in a 14% increase in ADG for steers grazing tall fescue. In an experiment with alfalfa diets, Dinius et al. (1978) reported that ADG increased 30% with a progesterone-estradiol implant. Rumsey and Hammond (1990) concluded that DMI must be 1.4 times the maintenance rate to achieve a 10% increase in BW gain by cattle implanted with estrogenic growth promoters. Thus, benefit from implanting pastured cattle is dependent on forage quality and availability.

Implantation of cattle grazing E+ tall fescue could enhance BW gain, but implantation with steroid hormones could affect health and stress levels from toxicosis. A grazing experiment was conducted to evaluate the interaction of stocking rate and implantation with BW gain on E+ tall fescue and to monitor heat stress related to fescue toxicosis after placement on a fescue-free diet.

MATERIALS AND METHODS

An 84-d grazing experiment was conducted in 2003 and 2004 at Booneville in west-central Arkansas. The Animal Use and Care Committee at the USDA-ARS Dale Bumpers Small Farms Research Center approved all procedures.

Grazing Experiment

In each of 2 yr, 36 crossbred yearling steers (*Bos taurus*) were randomly allotted to eight 1-ha pastures of Kentucky-31 E+ tall fescue. Treatments were arranged as a 4×2 factorial. Stocking rate (3.0, 4.0, 5.0, and 6.0 steers/ha) and ear implantation (with or without Synovex-S; 200 mg of progesterone and 20 mg of estradiol benzoate; Fort Dodge Animal Health, Fort Dodge, IA) combinations were assigned to pastures in a completely randomized design without replication (Riewe, 1961; Bransby et al., 1988). Treatment combinations were rerandomized in 2004.

On the initial days of grazing (19 March 2003 and 24 March 2004), all steers were dewormed with ivermectin (Ivermec, Merial Limited, Duluth, GA) and implanted if assigned to the implant treatment. After 6 d of adjustment to pastures, steers were weighed unshrunk to obtain initial BW [288 ± 24 (SD) kg in 2003 and 270 ± 34 kg in 2004]. Unshrunk BW also was taken on d 56 and 84, and implanted cattle were reimplanted on d 56.

On the initial day of the adjustment period (d 6) and on d 84, blood was collected (approximately 10 mL) from the median caudal vein at the base of the tail. Within 5 h of collection, blood samples were centrifuged (3,000 ×g for 30 min) to obtain serum, which was stored frozen (0°C). Serum was assayed for prolactin by RIA, following procedures described by Bernard et al. (1993). Intra- and interassay CV were 2.0 and 5.0%, respectively, for 2003 samples and 8.8 and 16.5%, respectively, for 2004

samples. Hair coat conditions were rated as sleek, rough, or transitional (i.e., some roughness of hair over the rump and shoulder regions).

Pastures were grazed continuously for 84 d; grazing was terminated on 17 June 2003 and on 23 June 2004. A mineral and vitamin supplement (Nutrena Feeds Division, Cargill Inc., Kansas City, KS) was offered ad libitum and contained Ca (minimum 12.0%, maximum 14.0), P (minimum 12.0%), Na (minimum 4.6%, maximum 5.9%), Mg (minimum 1.25%), K (minimum 1.25%), Cu (minimum 21 ppm), Se (minimum 18 ppm), Zn (minimum 300 ppm), vitamin A (minimum 440,000 IU/kg), vitamin D_3 (99,000 IU/kg), and vitamin E (33 IU/kg).

Pastures were fertilized with N on 13 March 2003 at a rate of 67 kg/ha, with N, P, and K on 30 January 2004 at rates of 67, 29, and 56 kg/ha, respectively, and with N on 12 March 2004 at a rate of 67 kg/ha. Forage availability was monitored with a disk meter that was similar in design to one described by Bransby et al. (1977), with the exception that the falling plate was 45 cm in diameter and weighed 1.9 kg. Disk meter height was recorded for 50 random locations within each pasture at 14-d intervals by taking 50 disk meter readings per pasture. In the second year, when disk meter heights were collected, forage was clipped to ground level beneath the disk meter plate for 3 locations in each pasture. These samples were dried at 60°C in a forced-air oven for 48 h and weighed; DM per unit of land area was subsequently regressed on disk meter height.

Postgraze Monitoring

In the second year, after termination of grazing, the 36 steers were maintained as a single group on a pasture (approximately 0.4 ha) of bermudagrass and offered free-choice bermudagrass hay and water. Rectal temperatures were determined, and blood samples were collected at 0800 on trial d 84, 85, 86, 87, 90, 92, and 94, which represent 24 (d 85), 48, 72, 144, 192, and 240 h after placement on nontoxic forage. Blood samples were processed and assayed for prolactin, as described earlier.

Heat indices for maximum and minimum temperatures and associated relative humidities were calculated for 22 June (d 0) through 2 July (d 10) with an equation described by Tarazon-Herrera et al. (1999). Weather data was collected from a weather station that was within 1 km of the experimental site.

Statistical Analyses

Average daily gain, forage availability, and serum prolactin were analyzed using Proc Mixed of SAS (SAS Inst. Inc., Cary, NC) to assess effects of stocking rate, year, implantation, and interactions among the 3 experimental variables. Pasture was used as the experimental unit in the analyses. Implantation and year were evaluated as dummy variables, and stocking rate was

analyzed as a regression variable, with deviations from the regression used as the error term (Riewe, 1961; Bransby et al., 1988). Quadratic equations for the relationship between BW gain per hectare and stocking rate were derived from calculated linear equations for the ADG stocking rate relationships (Jones and Sandland, 1974; Bransby et al., 1988; Aiken and Bransby, 1992b) for implanted and nonimplanted steers. Estimated BW gains per day, determined from the quadratic equations, were multiplied by the number of days that the pastures were grazed to estimate total BW gain over the experimental period.

Distributions of hair coat ratings were analyzed for year and implantation effects using Chi-Square tests with Proc Freq. Steer numbers per stocking rate were too low to provide reliable analysis of a stocking rate effect.

Models for analyzing rectal temperature and serum prolactin during postgraze recovery evaluated implantation as a discrete variable, stocking rate and hours on fescue-free diet (**HFFD**) as continuous variables, and interactions of all combinations of the discrete and continuous variables (linear, quadratic, and cubic regression coefficients). Although steers were kept as a single group during the postgraze phase, pasture was used as the experimental unit to evaluate carryover effects of stocking rate and implantation. The HFFD variable was evaluated as a repeated measure using the spatial power covariance structure of Proc Mixed. Insignificant ($P > 0.05$) variables were removed from the models using backwards-stepwise regression.

RESULTS AND DISCUSSION

Forage Availability

Pastures used in the experiment were reported by Aiken et al. (1998) to have greater than 75% infection levels. Therefore, infection levels for the present experiment were either similar or greater (Shelby and Dalrymple, 1993).

Forage availability declined linearly ($P < 0.001$) as stocking rate increased, and the regression intercept was greater ($P < 0.001$) in 2004 than in 2003 (Figure 1). Implantation did not affect ($P = 0.49$) forage availability and did not interact ($P > 0.10$) with stocking rate or year. Greater forage growth in 2004 compared with 2003 was likely because of greater rainfall observed in that year and the additional application of N fertilizer.

Weight Gain

There was no year effect ($P = 0.94$) on ADG; however, stocking rate interacted ($P < 0.05$) with implantation in affecting BW gain (Figure 2). Average daily gain of implanted steers declined ($P < 0.01$) as stocking rate increased; the slope for the nonimplanted steers did not differ from 0 ($P > 0.10$). Aiken and Piper (1999) reported a similar weak ADG response to stocking rate for non-
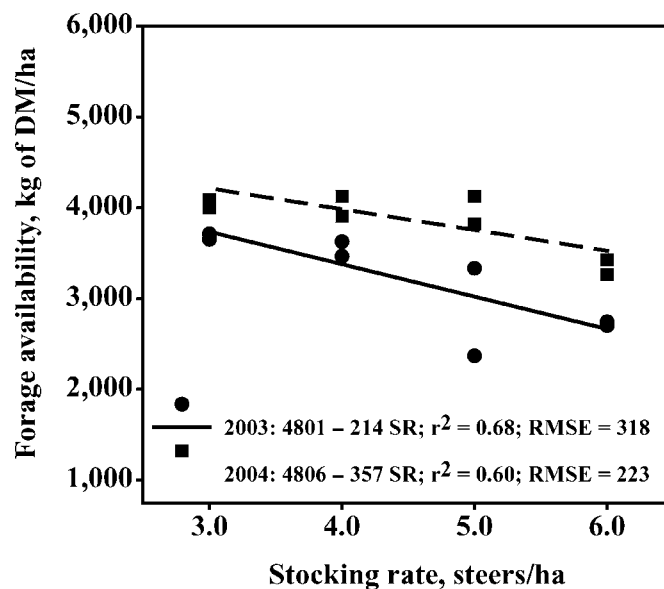

Figure 1. Linear regressions between mean forage availability and stocking rate (SR) in 2003 and 2004 during 84 d of grazing. Individual observations for each regression line were for both implanted or nonimplanted pasture treatments. Root mean square error (RMSE) values are provided in the legend.

implanted steers grazing E+ tall fescue with the same stocking rates as in the present experiment. However, declines in available forage with increases in stocking
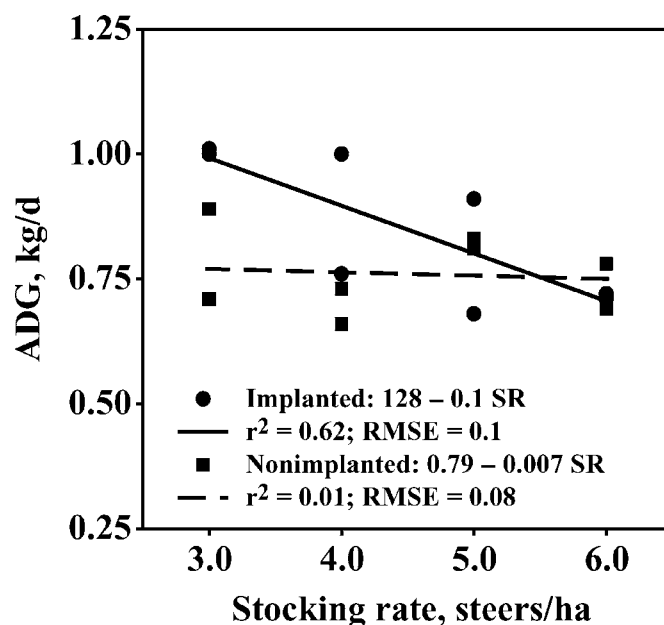

Figure 2. Linear regressions between ADG and stocking rate (SR) and ADG for implanted and nonimplanted steers grazed on endophyte-infected tall fescue. Individual observations for each regression line were for both 2003 and 2004. Root mean square error (RMSE) values are provided in the legend.

rate beyond those in the experiment would likely reduce ADG.

Average daily gain for the 3.0 steers/ha rate was approximately 1.0 kg/d with implantation and was approximately 0.75 kg/d without implantation. Bransby et al. (1994) reported a strong synergistic effect on ADG of steers with the combined use of steroidal implants and invermectin dewormer. Average daily gain at 2 locations with highly infected tall fescue increased 13% with steroidal implants and no dewormer, 21% with dewormer and no implantation, and 76% with both in combination.

Average daily gain without implantation was greater compared with previous grazing experiments with E+ fescue. Paterson et al. (1995) reported a range in ADG of 0.20 to 0.62 kg/d for experiments conducted with steers grazing highly infected tall fescue. Milder temperatures recorded in the late months of both grazing seasons may have improved ADG in the present experiment. The 2 regression lines intersected at 5.3 steer/ha, indicating that implantation had no effect on ADG with the heaviest grazing intensity. Positive response to implantation with lower stocking rates suggests that implantation increases forage consumption if forage availability is not limited. Although an implantation effect on forage availability was not detected, methodologies used to estimate forage availability generally lack the sensitivity to detect small differences in availability among treatments presumably affected by DM intake (Aiken and Bransby, 1992a).

Total BW gain per hectare for implanted steers showed a quadratic trend as stocking rate increased (Figure 3). Although a quadratic relationship was derived for nonimplanted steers, lack of an ADG response to stocking rate resulted in a linear trend of total BW gain per hectare as stocking rate increased. Trends in BW gain per hectare indicated that the 6.0 steer/ha rate, with or without implantation, provided approximately a 75% increase in BW gain per hectare over the 3.0 steer/ha rate.

Hair Coat Ratings

At the conclusion of grazing there was a difference ($P < 0.05$) in hair coat ratings between years. In 2003, more steers had transitional (58%) hair coats, whereas 66% of steers had rough hair coats in 2004. Transitional hair coats are associated with shedding of winter hair coats or by genetics (Olson et al., 2003). Greater incidence of transitional hair coats in 2003 suggests these steers were less affected by fescue toxicosis than those in 2004; however, this did not correspond with greater steer ADG in 2003 than in 2004. Hair coat distributions did not differ ($P > 0.10$) between implanted and nonimplanted steers, which indicated the steroid hormones did not influence shedding of winter hair coats. This supports results of Coffey et al. (2001), who concluded with steers grazing high and low E+ tall fescue that
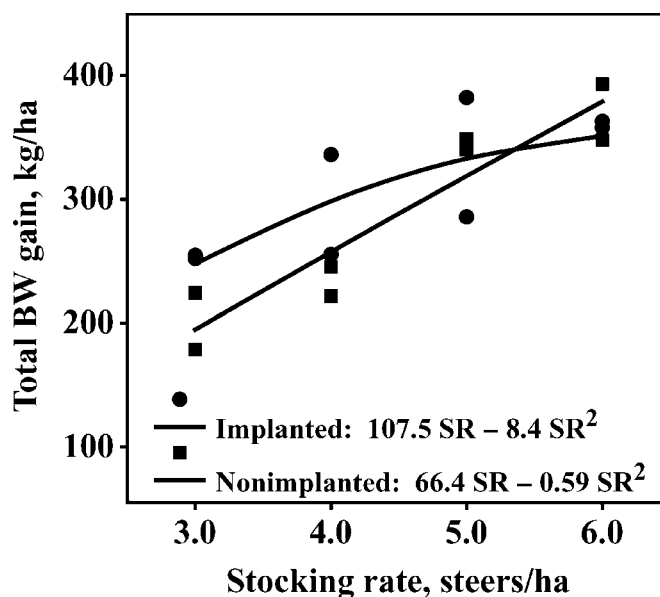

Figure 3. Mathematically derived relationships between total BW gain per hectare and stocking rate (SR) for implanted and nonimplanted steers; total BW gain per hectare was calculated as per Jones and Sandland, 1974. Individual observations for each regression line were for implanted and nonimplanted pasture treatments.

implantation with trenbolone acetate had no effect on the shedding of winter hair coats.

Postgraze Monitoring

Rectal Temperature. Mean rectal temperature at termination of grazing was 40.6°C for implanted steers and 40.2°C for nonimplanted steers. There was no carryover effect of stocking rate ($P = 0.16$), but the regression intercept was greater ($P < 0.05$) for implanted than for nonimplanted steers, and magnitude of the differences did not change ($P = 0.87$) during the monitoring phase (Figure 4). Rectal temperatures showed a quadratic decrease ($P < 0.001$) as HFFD increased. Rectal temperature increased during the first 24 HFFD, stabilized between 24 and 144 HFFD, and decreased between 144 and 240 HFFD.

Heat indices with the maximum and minimum temperatures and humidities were somewhat stable during the experimental period (Figure 5). There was a sudden drop in the indices with maximum ambient temperature and humidity for d 8 when maximum air temperature declined from the previous day (29.4 to 25.1°C). This corresponded with a decline in rectal temperature between 144 and 192 HFFD; however, rectal temperature was recorded early at 0800 when ambient temperature was closer to the daily minimum than the maximum. Furthermore, rectal temperature decreased between 192 and 240 HFFD, which occurred during a period when the indices increased relative to those measured on d 8 (144 HFFD).
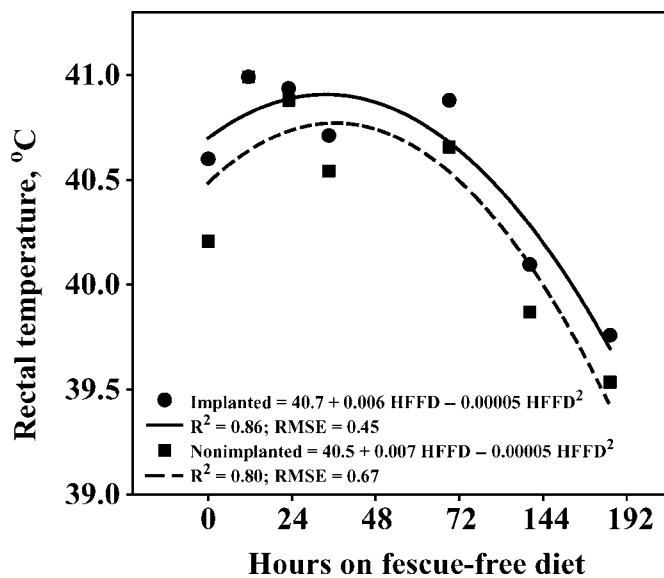
Figure 4. Relationship between hours on fescue-free diet (HFFD) and rectal temperature for implanted and nonimplanted steers grazed on endophyte-infected tall fescue. Root mean square error (RMSE) values are provided in the legend.

Mean rectal temperature on d 10 was 39.8°C for implanted and 39.6°C for nonimplanted steers, which are greater than 39.2°C specified by Smith (1986) as indicative of a healthy bovine. Ambient temperature affects rectal temperature (Cole, 1993), and the last measures could have been partially influenced by the warmer temperatures during the monitoring phase of this experiment. Final rectal temperatures, however, were considerably lower than those at termination of grazing and had declined to temperatures that indicate that severe heat stress was alleviated. Aiken et al. (2001) reported rectal temperatures of 39.9°C at 10 h after removal from E+ fescue pastures to decline linearly to less than 39.2°C at 82 h, which is less than the 144 to 196 h needed to reduce heat stress in the present experiment.

Research is lacking on effects of estrogen and progesterone on thermoregulation in cattle; however, cattle implanted with progesterone-estradiol benzoate growth promotants have shown slight increases in plasma thyroxine (**T4**) and reductions in plasma triiodothyronine (**T3**), resulting in an increase in plasma T4:T3 ratio (Kahl et al., 1978; Rumsey et al., 1992). Rumsey et al. (1997) reported an increase in T4 and thyroid-stimulating hormone in cattle implanted with progesterone-estradiol growth promoter. Al-Haidary et al. (2001) reported T4 to decrease in nonimplanted heifers when they were moved from a thermoneutral environment (21°C) to a heat challenge (31°C). Elevated rectal temperature for implanted steers in the present experiment could have been due to greater basal metabolism stimulated by a shift in thyroid status mediated by the estrogenic growth promoter.
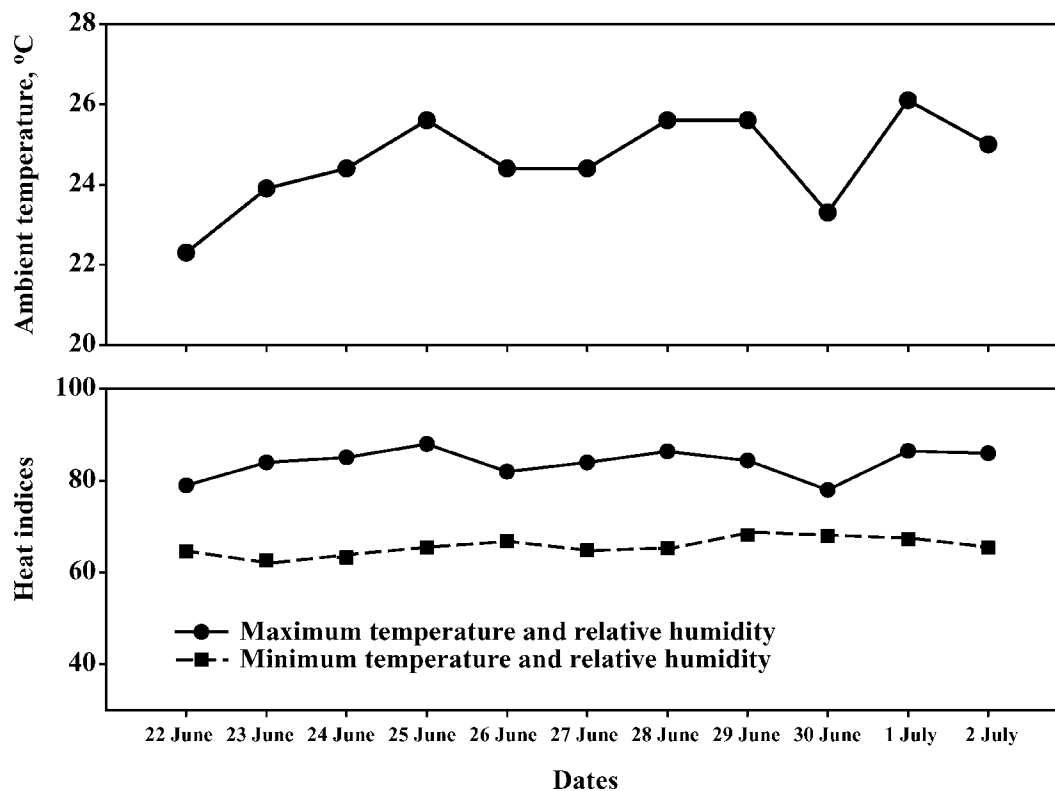

Figure 5. Ambient temperature and heat indices at maximum and minimum daily temperatures during the postgraze monitoring phase.

a.

Implanted

Prolactin = 50.0 − 1.4 SR + 1.5 HFFD − 0.01 HFFD − 0.01 $HFFD^2$ + 0.00003 $HFFD^3$

R^2 = 0.91; RMSE = 9.9

b.

Nonimplanted

Prolactin = 126.4 − 20.5 SR + 1.1 HFFD − 0.01 HFFD − 0.01 $HFFD^2$ + 0.00002 $HFFD^3$
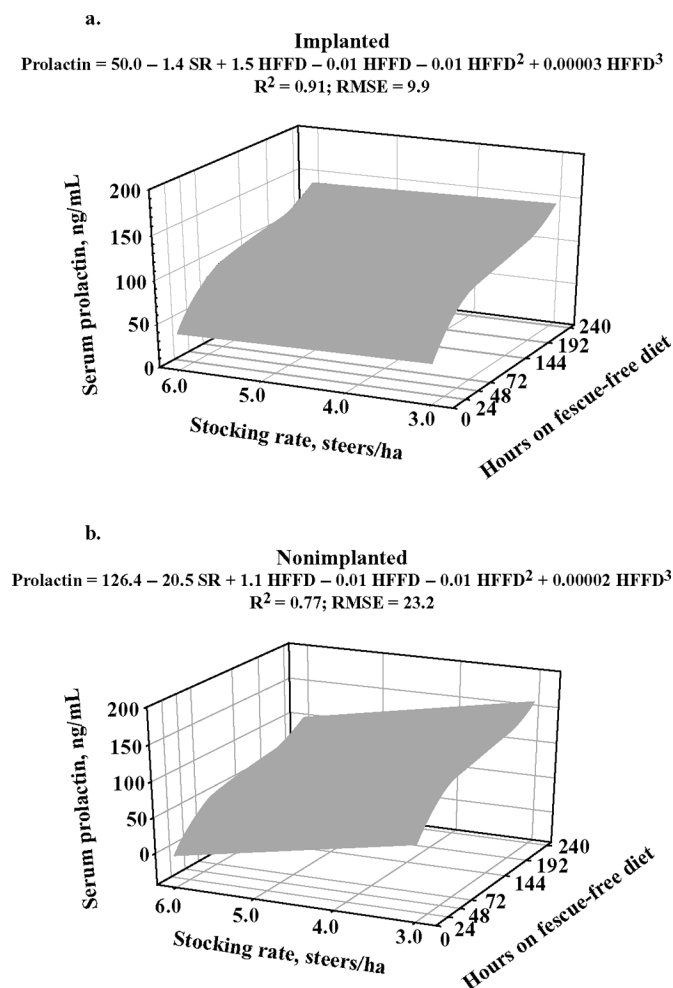
R^2 = 0.77; RMSE = 23.2

Figure 6. Relationship between hours on fescue-free diet and serum prolactin concentrations for (a) implanted and (b) nonimplanted steers grazed on endophyte-infected tall fescue. Root mean square error (RMSE) values are provided in the legend.

Serum Prolactin. Baseline measures of serum prolactin at initiation of grazing averaged 138.5 ± 24.0 ng/mL in 2003 and 146.6 ± 23.5 ng/mL in 2004, and at termination of grazing it was 20.2 ± 3.4 ng/mL in 2003 and 28.9 ± 6.0 ng/mL in 2004. Serum prolactin has not been directly related to the incidence of toxicosis (Strickland, et al., 1993) but is typically used as a marker of toxicosis (Sleper and West, 1996). Prolactin production in the anterior pituitary is inhibited by dopamine (MacLeod and Lehmeyer, 1974; Ben-Jonathan and Hnasko, 2001). Sibley and Creese (1983) reported that ergopeptines serve as dopaminergic agonists with strong affinity with D2 dopamine receptors of the anterior pituitary. Therefore, prolactin serves as an indicator of dysfunction in the endocrine system related to circulating ergopeptines.

There was a curvilinear increase in serum prolactin as HFFD increased (Figure 6), and the cubic ($P < 0.0001$) trend was similar between implanted and nonimplanted steers. General trend was for a substantial in-

crease in prolactin between 0 and 72 HFFD, followed by slight increases between 72 and 192 HFFD and a more substantial increase between 192 and 244 HFFD. Therefore, serum prolactin did not reach a stabilized concentration by 244 HFFD. Stuedemann et al. (1998) reported for steers switched from E+ to endophyte-non-infected tall fescue pasture that urinary alkaloid concentrations declined 67% within 24 h. After being switched from endophyte-noninfected to E+ tall fescue, these steers had urinary alkaloid concentrations after 24 h that were similar to those continually grazed on E+ tall fescue. Results of the present experiment support a rapid excretion of alkaloids; however, gradual increases in serum prolactin after 72 HFFD indicate that small concentrations of alkaloids remain in circulation.

Serum prolactin decreased as stocking rate increased for nonimplanted ($P < 0.05$) but not for implanted ($P > 0.10$) steers. As available forage increased with decreases in stocking rate, forage has been shown to accumulate and mature with low stocking, which could have a negative influence on DMI. Conversely, a greater proportion of immature forage with greater stocking rates could have a positive influence on DMI. Ergot alkaloid concentrations in tall fescue have been reduced with frequent close defoliations (Belesky and Hill, 1997); however, it is possible that greater consumption with greater stocking rates resulted in greater intake of alkaloids relative to low stocking rates. For nonimplanted steers, greater serum prolactin concentrations with low stocking rates were likely caused by the negative influence that the mature, stemmy available forage had on DMI and, hence, ergot alkaloids.

IMPLICATIONS

Implantation improved average daily gain on endophyte-infected tall fescue with low stocking rates. Although there was no response to steroidal implants with greater stocking rates, high body weight gain per unit land area can be achieved with greater stocking rates without declines in average daily gain. Steroidal implants do not appear to reduce the incidence of fescue toxicosis; however, steroidal implants increased rectal temperature, which could exacerbate the heat stress associated with grazing toxic fescue. Postgraze rectal temperatures were reduced, and serum prolactin was increased substantially in the 6 to 8 days after the steers were placed on a fescue-free diet. High average daily gain on tall fescue can be achieved with steroidal implants and low stocking rates, but heat stress from toxicosis could be of concern, particularly in hot, humid environments. Heat stress can be alleviated for steers grazed on endophyte-infected tall fescue by placing them on a fescue-free diet for 6 to 10 days. However, because the treatments used in this study were not replicated, these observations need to be confirmed with replicated studies.

LITERATURE CITED

Aiken, G. E., D. M. Ball, E. L. Piper, and C. P. West. 1998. Performance of steers fed a broiler litter-corn mixture on endophyte-infested and non-infested tall fescue. Prof. Anim. Sci. 14:51–55.

Aiken, G. E., and D. I. Bransby. 1992a. Observer variability for disk meter measurements of forage mass. Agron. J. 84:603–605.

Aiken, G. E., and D. I. Bransby. 1992b. Technical note: Stocking equivalents and stocking rate-gain relationships for steers and cow-calf pairs grazing oversown bermuda grass. J. Anim. Sci. 70:3234–3237.

Aiken, G. E., and E. L. Piper. 1999. Stocking rate effects on steer performance for two methods of alleviating fescue toxicosis. Prof. Anim. Sci. 15:245–252.

Aiken, G. E., E. L. Piper, and C. R. Miesner. 2001. Influence of protein supplementation and implant status on alleviating fescue toxicosis. J. Anim. Sci. 79:827–832.

Al-Haidary, A., D. E. Spiers, G. E. Rottinghaus, G. B. Garner, and M. R. Ellersieck. 2001. Thermoregulatory ability of beef heifers following intake of endophyte-infected tall fescue during controlled heat challenge. J. Anim. Sci. 79:1780–1788.

Belesky, D. P., and N. S. Hill. 1997. Defoliation and leaf age influence on ergot alkaloids in tall fescue. Ann. Bot. 79:259–264.

Ben-Jonathan, N., and R. Hnasko. 2001. Dopamine as a prolactin (PRL) inhibiter. Endo. Rev. 22:724–763.

Bernard, J. K., A. B. Chestnut, B. H. Erickson, and F. M. Kelly. 1993. Effects of prepartum consumption of endophyte-infected tall fescue on serum prolactin and subsequent milk production. J. Dairy Sci. 76:1928–1933.

Bransby, D. I., B. E. Conrad, H. M. Dicks, and J. W. Drane. 1988. Justification for grazing intensity experiments: Analyzing and interpreting grazing data. J. Range Manage. 41:274–279.

Bransby, D., D. Kee, S. Sladden, J. Eason, and J. Owen. 1994. Fighting fescue toxicity. Highlights Agric. Res. Alabama Agric. Exp. Stn. 41:3–4.

Bransby, D. I., A. G. Matches, and G. F. Krause. 1977. Disk meter for rapid estimation of herbage yield in grazing trials. Agron. J. 69:393–396.

Coffey, K. P., W. K. Coblentz, J. B. Junphry, E. L. Piper, C. F. Rosenkrans, Jr., D. S. Hubbell, III, K. F. Harrison, T. M. Denard, F. W. Pohlman, D. H. Hellwig, L. B. Daniels, and L. J. McBeth. 2001. Growth performance and serum prolactin concentrations of stocker steers implanted with trenbolone acetate while grazing endophyte-infected fescue in the spring. Prof. Anim. Sci. 17:166–173.

Cole, N. A. 1993. Nutritional management of stressed and morbid calves. Pages 178–179 in Current Veterinary Therapy: Food Animal Practice. 3rd ed. J. L. Howard, ed. W. B. Saunders Co., Philadelphia, PA.

Dinius, D. A., H. K. Goering, R. R. Oltjen, and H. R. Cross. 1978. Finishing beef steers on forage diets with additives and supplemental lipid. J. Anim. Sci. 46:761–768.

Hemken, R. W., J. A. Boling, L. S. Bull, R. H. Hatton, R. C. Buckner, and L. P. Bush. 1981. Interaction of environmental temperature and anti-quality factors on the severity of summer fescue toxicosis. J. Anim. Sci. 52:710–714.

Jones, R. J., and R. L. Sandland. 1974. The relation between animal gain and stocking rate. J. Agric. Sci. Camb. 83:335–342.

Kahl, S., J. Bitman, and T. S. Rumsey. 1978. Effect of Synovex-S on growth rate and plasma thyroid hormone concentrations in beef cattle. J. Anim. Sci. 46:232–237.

MacLeod, R. M., and J. E. Lehmeyer. 1974. Studies on the mechanism of the dopamine- mediated inhibition of prolactin secretion. Endocrinology 94:1077–1085.

Olson, T. A., C. Lucena, C. C. Chase Jr., and A. C. Hammond. 2003. Evidence of a major gene influencing hair length and heat tolerance in *Bos taurus* cattle. J. Anim. Sci. 81:80–90.

Paterson, J., C. Forcherio, B. Larson, M. Samford, and M. Kerley. 1995. The effects of fescue toxicosis on beef cattle productivity. J. Anim. Sci. 73:889–898.

Riewe, M. E. 1961. Use of the relationship of stocking rate to gain of cattle in an experimental design for grazing trials. Agron. J. 53:309–313.

Rumsey, T. S., T. H. Elsasser, and S. Kahl. 1997. Roasted soybeans and an estogenic growth promoter affect the thyroid status of beef steers. J. Nutr. 126:352–358.

Rumsey, T. S., and A. C. Hammond. 1990. Effects of intake level on metabolic response to estrogenic growth promotants in beef steers. J. Anim. Sci. 68:4310–4318.

Rumsey, T. S., A. C. Hammond, and J. P. McMurtry. 1992. Response to reimplanting beef steers with estradiol benzoate and progesterone: Performance, implant, absorption pastern, and thyroxine status. J. Anim. Sci. 70:995–1001.

Schmidt, S. P., and T. G. Osborn. 1993. Effects of endophyte-infected tall fescue on animal performance. Agric. Ecosyst. Environ. 44:233.

Shelby, R. A., and L. W. Dalrymple. 1993. Long-term changes of endophyte infection in tall fescue stands. Grass Forage Sci. 48:356–361.

Sibley, D. R., and I. Creese. 1983. Interactions of ergot alkaloids with anterior pituitary D-2 dopamine receptors. Mol. Pharm. 23:585–593.

Sleper, D. A., and C. P. West. 1996. Tall fescue. Pages 471–502 in Cool-Season Forage Grasses. L. E. Moser, D. R. Buxton, and M. D. Casler, ed. Agron. Monogr. No. 34. ASA, CDDA, and SSSA, Madison, WI.

Smith, R. A. 1986. Backgrounding and stocker calf management. Pages 161 in Current Veterinary Therapy: Food Animal Practice. 2nd ed. J. L. Howard, ed. W. B. Saunders Co., Philadelphia, PA.

Strickland, J. R., J. W. Oliver, and D. L. Cross. 1993. Fescue toxicosis and its impact on animal agriculture. Vet. Hum. Toxicol. 35:454–464.

Stuedemann, J. A., N. S. Hill, F. N. Thompson, R. A. Fayrer-Hosken, W. P. Hay, D. L. Dawe, D. H. Seman, and S. A. Martin. 1998. Urinary and biliary excretion of ergot alkaloids from steers that grazed endophyte-infected tall fescue. J. Anim. Sci. 76:2146–2154.

Tarazon-Herrera, M., J. T. Huber, J. Santos, H. Mena, L. Nusso, and C. Nussio. 1999. Effects of bovine somatotropin and evaporative cooling plus shade on lactation performance of cows during summer heat stress. J. Dairy Sci. 82:2352.

Thompson, F. N., J. A. Studemann, and N. S. Hill. 2001. Anti-quality factors associated with alkaloids in eastern temperate pasture. J. Range Manage. 54:474–489.